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USE OF DYNAMITE TO RECOVER TAGGED SALMON

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by

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ABSTRACT

Experiments were conducted in July 1959, on the Kvichak River at Igiugig, Alaska, to determine the effect on adult salmon of an underwater explosion of dynamite and to determine whether dynamite could be used to recover tagged salmon from large rivers.

The experiments show that dynamite is an effective means of killing salmon and that the direction and lethal range of the blast can be controlled by varying the charge strength and water depth, and by the use of deflectors.

Techniques for the use of dynamite in tag recovery work were devised and put into use at the Kvichak counting sites where they proved successful in the recovery of four tags.

Experiments involving the underwater detonation of dynamite were conducted for two purposes: To determine the effectiveness of an underwater explosion in killing or immobilizing adult salmon, and to determine if dynamite could be effectively used to recover tagged salmon from large Bristol Bay rivers.

Since 1956 the Fisheries Research Institute, under contract with the United States (Bureau of Commercial Fisheries), has conducted salmon tagging experiments each year in the offshore waters of the North Pacific and Bering Seas. These studies represent a part of the research program being carried out under the auspices of the International North Pacific Fisheries Commission of which Canada, Japan, and the United States are member nations. The purpose of this research is to determine the distribution of salmon at sea with respect to continent of origin. Many of these salmon are bound for the rivers of Bristol Bay, Alaska as evidenced by tag returns from the Bristol Bay gill-net fishery and from records of tagged salmon observations at counting stations along Bristol Bay rivers. In addition to these experiments, the U. S. Bureau of Commercial Fisheries has conducted several salmon tagging experiments in Bristol Bay estuaries since 1955.

With the adoption of towers in 1957 as a means of counting the escapement of adult salmon into Bristol Bay rivers, much difficulty has been experienced in recovering tagged salmon from this

[1] Contribution No. 75, College of Fisheries, University of Washington.

escapement. Spawning ground recovery has proven to be difficult, ineffective, and expensive. The ideal place to intercept a tagged fish is at the counting site where the entire escapement is funneled along each river bank and where tagged salmon are frequently seen to pass.

Recovery of tagged salmon is a major problem in a large river since the fish have an easy avenue of escape in deeper water. A salmon disturbed by an unsuccessful recovery attempt will generally continue its upstream migration in deep water beyond the range of visibility.

THE EFFECT OF DYNAMITE ON SALMON

During June of 1959, experiments on the effects of underwater explosions were conducted on the Kvichak River at Igiugig, Alaska. Tests were made in a backwater channel of the Kvichak River in water depths ranging from 2 to 6 feet. The bottom was a uniform mixture of sand and medium-sized gravel.

Blasting supplies consisted of 14-gage leading wire, 20-gage connecting wire, electric blasting caps, $1\frac{1}{4}$ by 8-inch sticks of 40-percent gelatin dynamite, and plastic electrician's tape.

Fish used in the experiments were mature male and female red salmon *(Oncorhynchus nerka)* which were obtained by beach seining in the main Kvichak River. During the experiments the salmon were contained in a small chicken-wire cage which could be suspended in the water at varying distances from the bottom.

Of the factors which control the effect of an underwater explosion, those recognized as being most important in tag recovery work are: water depth, distance of fish from charge, orientation of the fish with respect to the charge, elevation above the river bottom of either the fish or the charge, multiple charges, sympathetic detonation of multiple charges, strength of charge, and use of reflectors or deflectors. Variables tested include: (1) depth of water, (2) distance of fish from charge, (3) strength of charge, (4) use of reflectors and deflectors.

Observations made during preliminary experiments served to establish a criterion for determining the effects of a lethal explosion. Damage caused by a lethal explosion was remarkably similar in fish which were held at varying distances from the charge as long as they were within the lethal range of the charge. The only external damage noted in any of the fish was the disappearance of a small patch of scales from each side of the fish in the vicinity of the air bladder (fig. 1).

Figure 1.--External damage to salmon caused by underwater dynamite explosion.

The internal damage was concentrated in the organs and tissues surrounding the air bladder and consisted of ruptured air bladder, ribs torn loose from abdominal walls, kidney ruptured in most instances, ovaries or gonads torn, blood vessels ruptured in body wall, adipose tissue and spleen both torn.

Fish used in the lethal range experiments usually had been placed at or near the lethal limits of the pressure wave when killed. These fish often lived for five or ten minutes after the blast but

were incapable of coordinated swimming activity during this period. Their motions were similar in every case and easily detectable, thus making it possible without internal examination to determine when an explosion had had a lethal effect. These reactions may be described as follows: For the first few minutes the fish were very listless, either belly up or with tendency to roll onto side, breathing action very faint or undetectable, spasmodic flaring of opercula and gills. Later, there were observed continued spasms of the gill muscles, and periodic spurts of violent, uncoordinated lateral muscle contractions. Within ten minutes all fish had died.

Fish killed in tag recovery attempts were sometimes within a foot or two of the charge upon detonation. Internal damage to these fish was similar but slightly more extensive than in those killed on the periphery of the blast. These fish were either killed instantly or died shortly after the blast.

DESCRIPTION AND RESULTS OF VARIABLES TESTED

Effect of water depth on lethal range

Experiments using a charge strength of one-half stick were conducted to find the lethal range at varying water depths. The depths tested were 2, 3, 4, 5, and 6 feet. During testing at each of these depths the charge was placed directly on the bottom and the caged salmon were held within several inches of the bottom. The usual procedure was to place a fish at a desired distance from the charge and then detonate the charge. The fish was subsequently observed for a period of at least 15 minutes for signs of abnormal behavior. If none were visible the distance was decreased by a foot. This process contained until abnormal behavior of the fish was observed indicating damage had occurred. Occasionally, fish appeared to be listless but these were capable of coordinated swimming motion for at least 15 minutes after the blast, and for the purposes of tag recovery, were considered to have escaped the effects of the blast. In each case where a fish showed abnormal behavior it was held in a live box for further observation.

The results of these experiments are shown in figure 2. The killing range in shallow water is short, being about 3 feet in 2 feet of water. The range increases rapidly in greater water depths to about 16 feet in 6 feet of water. The curve suggests a maximum range for a $\frac{1}{2}$-stick charge of about 18 feet.

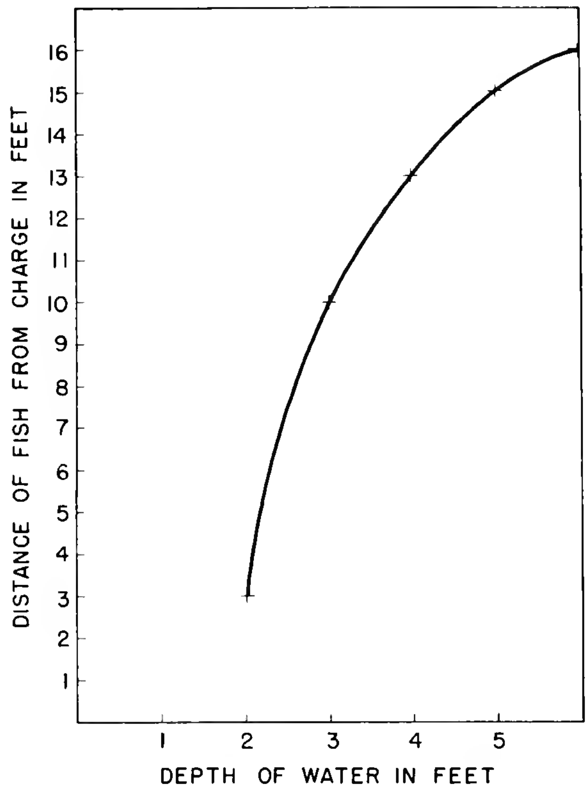

Figure 2.--Lethal range of one-half stick of dynamite in water of various depths.

The varying reflective qualities of bottom materials may greatly influence the lethal range of a given charge. Fine silt and mud sediment will more effectively absorb a portion of the pressure wave than will a hard-packed bottom material (Fox, 1950). Bottom materials over which the Kvichak experiments were conducted had good reflective qualities and may have increased the values obtained for the lethal ranges.

Effect of varying charge strength on the lethal range

Early in the testing it became obvious that small charges would be adequate for tag recovery purposes and for this reason

most of the experimentation was done with $\frac{1}{2}$-stick charges. In the relatively shallow water depths tested, it was found that much of the energy of a full-stick charge was lost in creating a large water geyser and produced but little increase in the lethal range of the pressure wave (fig. 3). At depths of less than 3 feet a $\frac{1}{2}$-stick charge was also excessive as evidenced by the large geyser produced. Experiments conducted at depths of 4 and 6 feet indicated that increasing the charge from one-half stick to one full stick resulted in roughly a 15 percent increase in the killing range.

Figure 3.--An explosion of $1\frac{1}{2}$ sticks of dynamite in 6 feet of water.

Effect of reflectors and deflectors

Sandbags filled with gravel and sand were used in these experiments to determine the possible effect on the pressure wage of a rock or irregular bottom contour as might be encountered in tag recovery work.

At the 4-foot depth, as previously shown, a $\frac{1}{2}$-stick charge had a lethal range of 13 feet. A sandbag placed 1 foot from the charge directly between the charge and the fish reduced the range in that direction to the extent that a fish 11 feet away was unharmed. A 6-inch hole was blown in the burlap material of the sandbag. No other depths or distances were tested with this arrangement.

In another experiment a platform made from concrete reinforcing rods and wire screen was used to support a sandbag 12 inches directly above the charge; the purpose being to direct the pressure wave in a horizontal direction and increase its lethal range. A fish placed at a distance of 17 feet from the charge in 4 feet of water was unharmed by the blast. The sandbag was blown apart and the supporting stand was tipped over, indicating that the reflective qualities of this setup were poor since much energy was absorbed in lifting and tearing the sandbag. This experiment was terminated since no materials were available for construction of a suitable reflector.

FISH RECOVERY WITH DYNAMITE AT COUNTING TOWER SITE

After the initial experiments were completed an electric blasting circuit was installed at counting tower No. 2 on the left bank of the main Kvichak River. Preliminary observations of the salmon migration paths during peak and slack periods were used to establish the correct placement of charges. The migration past tower No. 2 occurred over a width of 40 feet and in depths ranging from 3 to 6 feet. This area was adequately covered by 3 one-half stick charges placed at 10-foot intervals. The charges, as shown in figure 4, were placed about 10 feet upstream from the counting panels in order to be visible under the smooth water behind the ripple-dampener. This distance was found to be important since it allowed the observer time to make a more positive identification of a tagged salmon while it crossed the panels.

The circuit wires were run up to the tower platform and connected to either a 4-volt dry-cell battery or a plunger-type detonator. The battery, when connected into the circuit by a knife switch, was found to be the best method for detonating the charges since it is both easy to operate and safe against accidental discharge. The detonator was an excellent source of current but its operation required more attention by the operator.

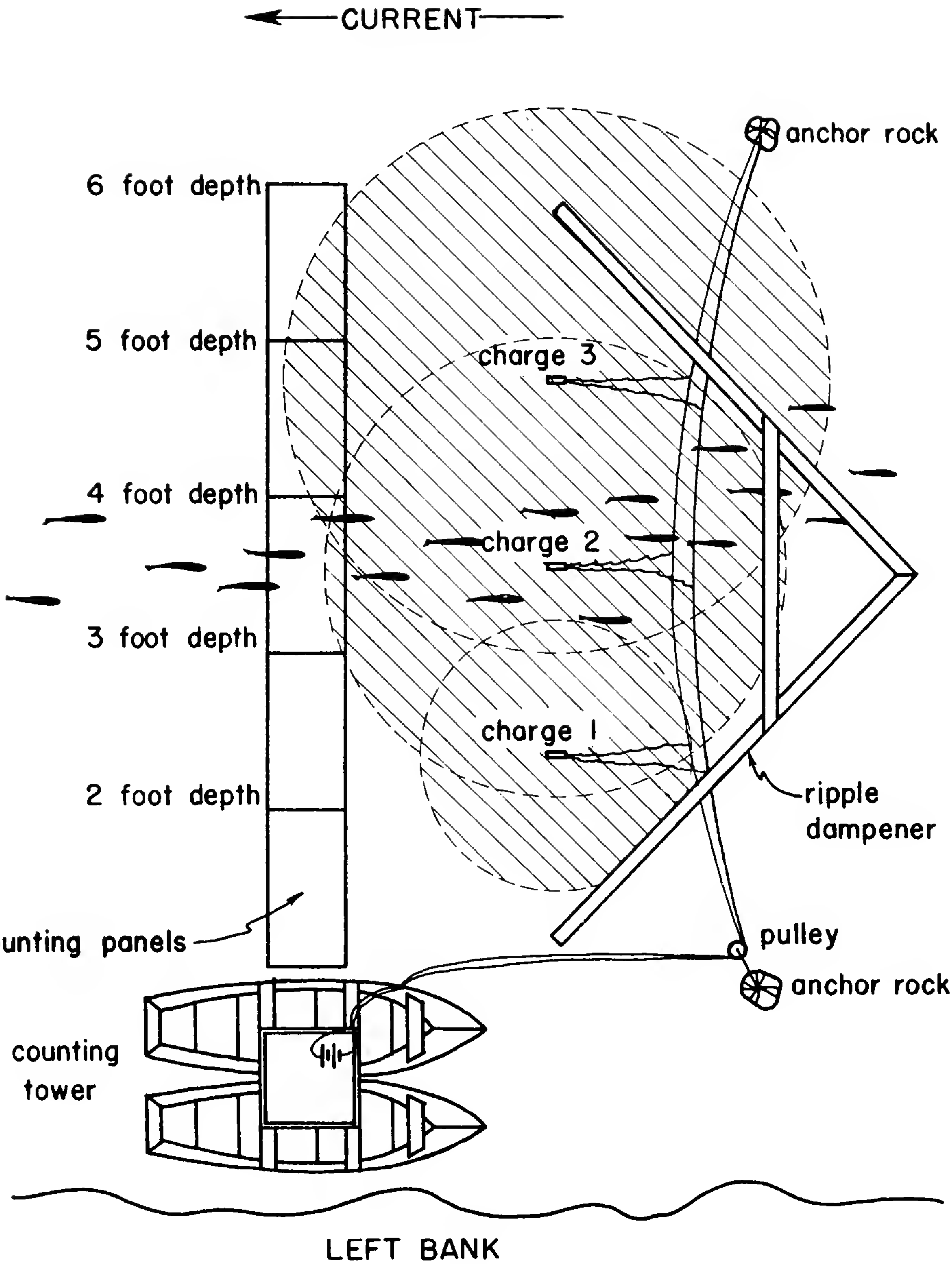

Figure 4.--Recommended placement of charges at counting tower site.

There were six recovery attempts made from the towers with this arrangement of the dynamite circuit. Of these attempts, only four were actually made on tag-bearing salmon, and each of these fish was successfully recovered.

The numbers of salmon killed during each of these attempts ranged from 11 to 22. These were recovered either by the tower watchman working alone from a skiff or assisted by one or two other men in a second skiff.

The fish killed by the explosions invariably sank to the bottom and rolled downriver with the current. They were retrieved by skiff using long-handled dip nets and spears.

CONSTRUCTION OF THE CIRCUIT

The preparation of the charges was simple and safe when proper methods were used and safety precautions followed. The 40-percent ammonia gelatin dynamite recommended for this use is relatively insensitive and less dangerous than other types. The electric blasting caps contain a small amount of highly sensitive explosives and were therefore handled with extreme care. At all times manufacturer's instructions for handling of caps and dynamite were carefully followed.

The recommended method for capping a charge (Institute of Makers of Explosives 1955) is shown in figure 5. Of the several methods commonly used for securing electric caps to dynamite, this method was found to offer the least resistance to water current.

The following tools were required for preparation of the charges: a sharp knife, a stick sharpened for punching the cap and wire holes in the dynamite, and waterproof rubber or plastic material for covering the charges. An unprotected charge remained effective for at least three days but would eventually become water-soaked and impossible to detonate.

In planning the circuit it was important to have an adequate source of current. As recommended in the "Handbook of Electric Blasting" (McFarland and Rolland 1959) at least 3/10 amperes of direct current or 6/10 amperes of alternating current should pass through each electric blasting cap in parallel circuit firing. To calculate the current required in a circuit, the resistances of the "EB" caps and leading wire were determined. Tables giving these values were obtained when purchasing the blasting supplies. The circuit diagram used at the counting tower sites and calculation of required voltage are shown in figure 6.

DISCUSSION OF PROBLEMS ENCOUNTERED

The use of dynamite at the counting tower sites presented several important difficulties. The first of these was in limiting the destruction of non-tag-bearing salmon. Since all salmon within the lethal range of the pressure wave are killed by the blast, it is desirable that the wave be limited or directed as much as possible to exclude these salmon. Even though the value of the information gained from the recovery of a tag may far surpass the value of salmon thus destroyed, it is a waste which should be limited if possible.

A second difficulty encountered was in retrieving the dead salmon after a blast. During the Kvichak tests long-handled dip nets and spears were used for this purpose with spearing proving to be the best method. In situations where deep pools are present below the tower sites there may be considerable difficulty in retrieving the salmon. In such a case it would not be advisable to attempt recovery by dynamite unless some type of a catching device was present.

A third difficulty was in the interruption of the migration by recovery activity during a recovery attempt. During the Kvichak recovery attempts all dead salmon were retrieved for examination purposes and this usually required from 20 to 30 minutes. In actual practice, when recovery activity may cease after the tagged salmon is retrieved, this time would be considerably shortened.

It is recognized that the disturbance caused by the blast, together with silt and chemicals released into the water and carried downriver, may alter the normal migration pattern so as to affect subsequent hourly migration counts. The Kvichak migration, however, was observed

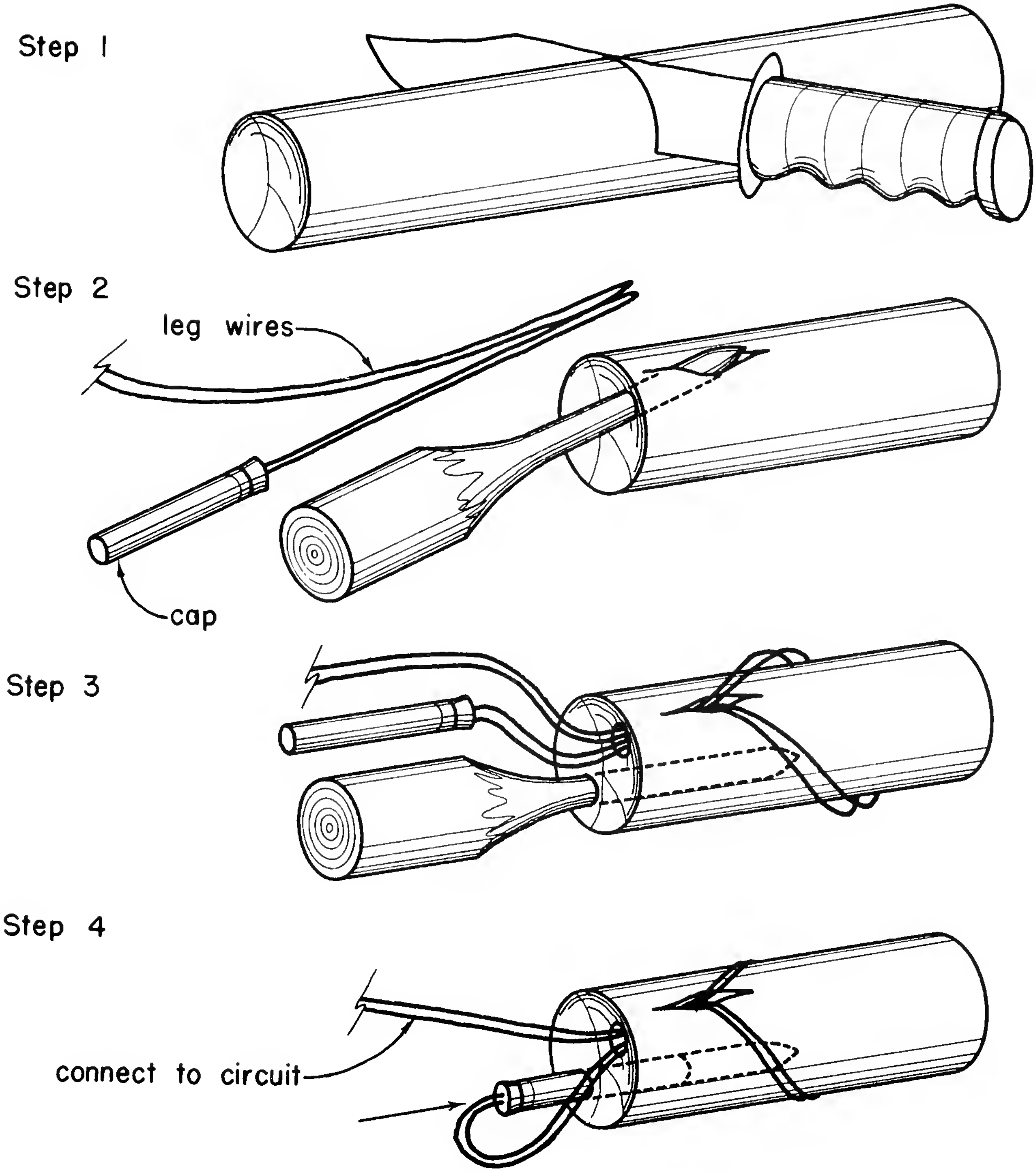

Figure 5.--Method of capping dynamite.

Step 1. Slice stick into equal halves with a sharp knife.
Step 2. Using a sharpened stick, punch a hole through the closed end and out one side. Unwrap 2 feet of cap leg wires and fold over 6 inches from the cap.
Step 3. Insert folded ends through the hole and loop them over the opposite end of the half-stick. Punch a second hole along the axis of the half-stick.
Step 4. Without forcing, slide the cap into the hole. Cover the charge with waterproof material and connect cap wires to leading wire circuit.

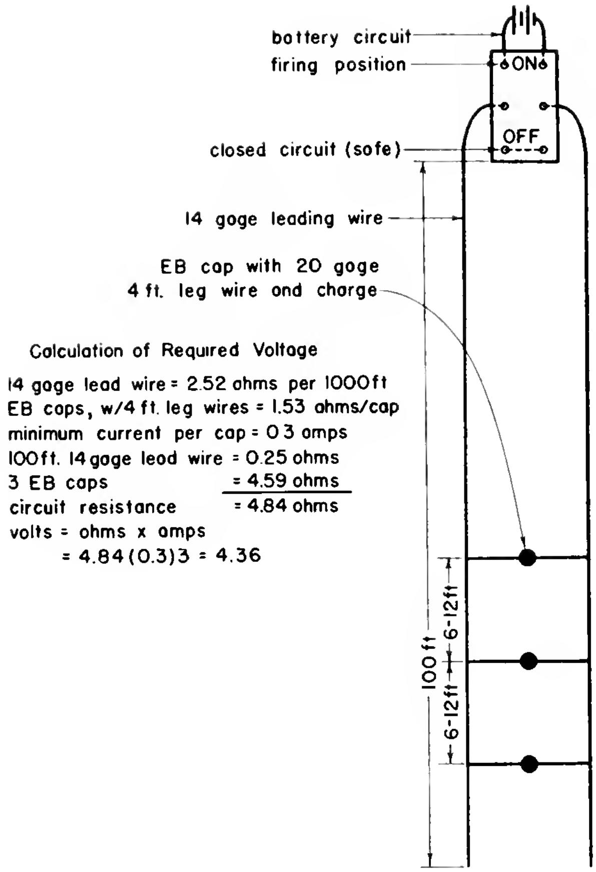

Figure 6.--Dynamite circuit used at the Kvichak River counting towers and calculation of required voltage.

to assume a normal pattern shortly after recovery activity ceased, and particularly so during heavy migration.

The counts for three days during which recovery attempts were made are shown in table 1. The hourly counts were of 10 minutes duration each and were made on or near the hour from tower No. 1 and about 15 minutes after the hour from tower No. 2. Of the five recovery attempts made on these days little or no effect on subsequent counts can be seen.

The 1959 Kvichak tag recovery effort emphasized the importance of positively identifying a tag from counting towers. The Kvichak recovery effort was intended to be limited to high seas tags from the 1958 and 1959 high seas tagging experiments. These tags consisted of ½-inch, white Petersen disc tags; 3/4-inch, red and white Petersen disc tags; and white spaghetti tags. During the Kvichak run four recovery attempts were made on tag-bearing salmon. In each of these attempts the observer was reasonably certain that the tag he saw was a high seas tag; however, when the fish were retrieved, three were found to be local Kvichak tags and one was a Fish and Wildlife Service Nushagak Bay tag. In two of these recoveries a yellow disc was mistaken for a white disc. In addition, two recoveries were made of salmon bearing predator scars which were mistaken for white disc tags.

The full-time observation periods were generally limited to times of good visibility when it was believed that a tag could be positively identified. Under ideal conditions of calm water surface, minimum surface glare, and clear water this probably was true but under average conditions it was difficult to distinguish a ½-inch disc tag from a 5/8-inch disc tag or a yellow tag from a white one.

CONCLUSION

An underwater explosion of dynamite was found to be a very effective means of killing adult red salmon. Negligible external damage to the fish occurred from the explosions, but there was extensive internal damage caused which apparently was due to the difference in density between the air bladder and surrounding organs and tissues.

In tests using ½-stick charges of 40-percent ammonium gelatin dynamite a direct relationship was found to exist between water depth and the effective killing range of the pressure wave. This range was increased by approximately 15 percent at the 4- and 6-foot depths by doubling the charge strength. It was also found that a solid object in the path of the pressure wave reduced the lethal range in that direction.

Dynamite can be effectively used in the recovery of tagged adult red salmon from large rivers. By the use of multiple, ½-stick dynamite charges the migration path can be completely covered. Detonation of the charges can be accomplished from the counting towers by the tower watchman.

TABLE 1.--Effect of recovery attempts on hourly 10-minute tower counts.

Hour of count	Tower No. 1 7/7/59		Tower No. 2 7/12/59		Tower No. 2 7/13/59	
	Time of detonation	10-minute count	Time of detonation	10-minute count	Time of detonation	10-minute count
00-01		165		0		1
01-02		381		2		16
02-03		451		0		15
03-04		376		58		-1
04-05		338		45		5
05-06		82		48		2
06-07		113		19		16
07-08		69		36		0
08-09		70		23		24
09-10	0900	No count		95		6
10-11		58		49	0930	4
11-12		124	1030	106		4
12-13		70		86		19
13-14		346		30		6
14-15		124		66		0
15-16	1530	249		31		8
16-17		299		6		48
17-18	1700	274		30		7
18-19		169		32		16
19-20		270		43		21
20-21		277		15		-3
21-22		250		31		4
22-23		247		79		0
23-24		113		4		0

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